NOLAN CREEK

Survey of Potential Bacteria and Nutrient Sources in the Nolan Creek/South Nolan Creek Watershed

Prepared for:

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SUMMARY

This survey was developed to aid in identifying potential bacteria and nutrient sources in the Nolan Creek/South Nolan Creek watershed. It provides an overview of stakeholder feedback on potential sources and visual assessment findings. Land use/land cover, estimates of animal and human population densities as well as an overview of potential point and nonpoint sources in the watershed were compiled to better characterize sources. A preliminary assessment of water quality data was also conducted as an indicator of dominant sources. As most of the watershed area associated with Segments 1218_02 and 1218C is comprised of urban land cover, urban sources were considered the likely dominate source in association with stormwater runoff. Other prominent sources, as perceived by stakeholders, included sanitary sewer overflows, pet waste, and failures of on-site sewage facilities. A visual assessment of the stream from monitoring locations along the creek indicated some limited contributions from wildlife, livestock, and birds. Only a limited number of livestock reside within the watershed, and no concentrated animal feeding operations. There are eight wastewater treatment facilities that discharge to the creek, which are direct point sources, but bacteria concentrations of these discharges are generally very low. On occasion, compliance issues have been documented with WWTFs or the collection system leading to elevated bacteria contributions from these sources. A preliminary review of water quality data indicated that bacteria concentrations were higher in association with storm events than during baseflow indicating a larger nonpoint source contribution of bacteria with rainfall runoff than during dry weather conditions. For nutrients (nitrate, orthophosphorus, and total phosphorus), a decrease in concentrations was noted with storm events in comparison to routine monitoring data indicating a stronger point source than nonpoint source signal as the potential source of nutrients. While nutrient concentrations, except ammonia, are not reported for the WWTF discharges in the watershed, general wastewater characteristics based on literature values and monitoring data indicate that WWTF discharges are likely the dominant source causing the higher nutrient concentrations in the watershed. This survey provides only an overview of potential sources, while future reports for this project will address loadings and relative source contributions.

For more information about this document or any other document TIAER produces, send email to info@tiaer.tarleton.edu. More information about the Nolan Creek/South Nolan Creek project can be accessed from the project website at: http://www.killeentexas.gov/nolancreekwatershed.

Cover photograph is South Nolan Creek at 38th Street in Killeen (station 18828) taken on September 10, 2014.

Table of Contents

List of Figures

List of Tables

SECTION 1

The Watershed and Water Body Conditions

The Nolan Creek/South Nolan Creek watershed comprises 72,800 acres and is located almost completely within Bell County with a small, northwest portion extending into Coryell County (Figure 1-1). South Nolan Creek has its headwaters near the City of Killeen and converges with North Nolan Creek to the west of Belton to form Nolan Creek. Municipalities within the watershed include Killeen, Harker Heights, Nolanville, and Belton. The Fort Hood Military Reservation also covers much of the northern portion of the watershed. Several small lakes and reservoirs exist throughout the watershed, although none are directly on the mainstem of Nolan or South Nolan Creek. Nolan Creek passes through the City of Belton and then converges with the Leon River as part of the Brazos River Basin.

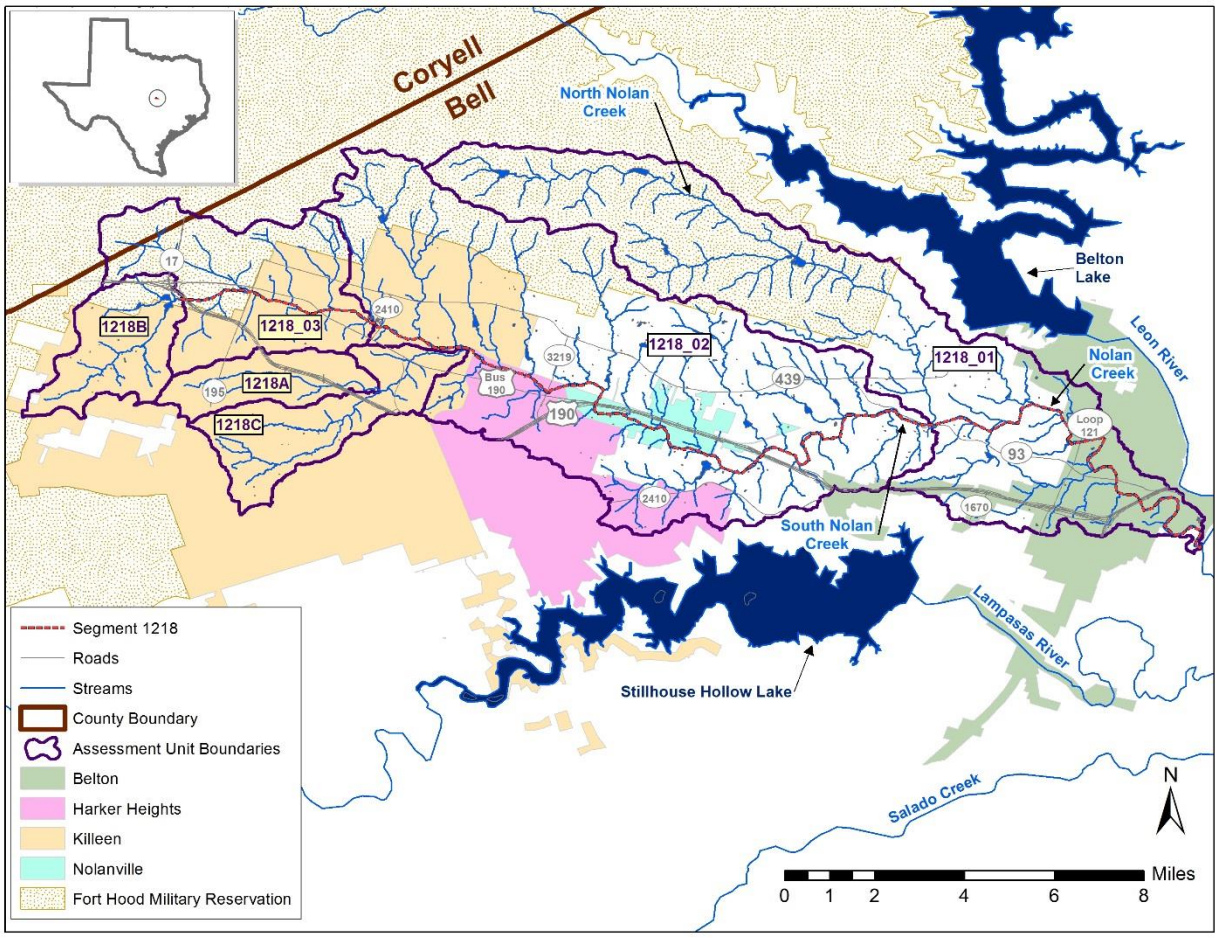

Figure 1-1 Watershed and assessment units associated with Segment 1218, Nolan Creek/South Nolan Creek. Insert shows the watershed location within the State of Texas.

Segments and assessment units (AUs) identified by the Texas Commission on Environmental Quality (TCEQ) in Figure 1-1 include the following:

- 1218: Nolan Creek/South Nolan Creek - from confluence with the Leon River in Bell County to a point 100 meters upstream to the most upstream crossing of US 190 and Loop 172 in Bell County.

- 1218_01: Portion of Nolan Creek from the confluence with the Leon River upstream to confluence with North Nolan/South Nolan Creek fork in Bell County.

- 1218_02: Portion of South Nolan Creek from confluence with North Nolan/Nolan Creek fork upstream to confluence with Liberty Ditch in City of Killeen in Bell County.

- 1218_03: Portion of South Nolan Creek from confluence with Liberty Ditch in Killeen upstream to a point 100 meters upstream of the most upstream crossing of US 190 near the intersection of US 190 and Loop 172 in Bell County.

- 1218A: Unnamed Tributary to Little Nolan Creek - from the confluence with Little Nolan Creek upstream to headwaters in the City of Killeen, Bell County.

- 1218B: South Nolan Creek - from 100 meters upstream of the most upstream crossing of US 190 near the intersection of US 190 and Loop 172 upstream to headwaters in the City of Killeen, Bell County.

- 1218C: Little Nolan Creek - from the confluence with Nolan Creek/South Nolan Creek upstream to headwaters in the City of Killeen, Bell County.

The 303(d) List within the 2012 Texas Water Quality Inventory includes bacteria as an impairment for assessment units (AUs) 1218_02 and 1218C for primary contract recreation (TCEQ, 2013a). Segment 1218_02 was first listed as impaired for bacteria in 1996, while water body 1218C was not listed until 2010. In addition to the bacteria impairment, concerns for elevated nitrate, total phosphorus, and orthophosphorus concentrations are noted for AU 1281_02 in the 2012 Texas Integrated Report for Clean Water Act Sections 305(b) and 303(d) (TCEQ, 2013b).

This report addresses Subtask 5.3 of the Clean Water Act Section 319(h) project, *Assessment of Water Quality and Watershed Based Planning for the Nolan Creek/South Nolan Creek*, in providing a survey of potential bacteria and nutrient sources within the Nolan Creek/South Nolan Creek watershed. This survey is based on a data inventory conducted for the watershed (see McFarland and Adams, 2015), stakeholder feedback from public meetings, visual observations, and a preliminary assessment of water quality data. Information within includes a review of land use/land cover, estimates of animal and human population densities as well as an overview of potential point and nonpoint sources in the watershed, including findings from previous studies. Information from this survey will be used in future project tasks to estimate loadings and load reductions needed to meet water quality goals.

SECTION 2

Visual Assessment and Stakeholder Evaluation

Stakeholder Evaluation

As part of the project, public meetings have been held biannually. In 2013 and 2014, meetings occurred on the following dates:

- July 31, 2013 in Killeen
- September 5, 2013 in Harker Heights
- January 16, 2014 in Killeen
- September 25, 2014 in Killeen

At each meeting, stakeholders have been requested to provide input regarding known or perceived sources of bacteria to Nolan Creek/South Nolan Creek. At the September 25, 2014 meeting, this was taken a step further in that an evaluation tool was presented that allowed stakeholders to provide written responses. The list below summarizes responses from eight stakeholders to the question "What do your feel are the major bacteria sources in or along Nolan/South Nolan Creek?":

- Storm water, pets, grackles/pigeons, septic systems
- Sanitary sewer leaks, OSSF (*on-site sewage facility*) failures
- Domestic animals, wildlife, farms, SSOs (*sanitary sewer overflows*), Ft Hood land disturbance
- Residential septic system, municipal sanitary sewer overflows
- Street/yard/ag runoff, livestock
- Storm water runoff from small feeder lines in east Killeen
- Unsure
- Wastewater plant emissions, sewage drainage during storms

These responses recognize the contributions of nonpoint sources associated with stormwater runoff, but also indicate issues with septic systems and unauthorized discharges from sewer collection system as contributing factors.

For reference, a listing of agency stakeholders contacted for this project is given in Appendix A. The full mailing list of stakeholders includes 149 individuals and use of at least 17 media outlets for meeting announcements. Most meetings have included both local television and newspaper coverage, and the project website, which is maintained by the City of Killeen as a project partner, provides an overview of project activities http://www.killeentexas.gov/nolancreekwatershed.

Visual Assessment

With the routine monthly monitoring program initiated in May 2013 for this project, the monitoring staff has been asked to document any potential sources encountered. While they are

not assessing the entire creek, the monitoring network includes 11 stations with 9 on the mainstem of the Nolan Creek/South Nolan Creek, 1 on Little Nolan Creek, and 1 on Long Branch (Figure 2-1). This visual assessment has noted the following as potential bacteria sources:

- Some deer pellets near Station 11905 at Backstrom Crossing as rural wildlife,
- Raccoon tracks near Station 11913 at Roy Reynolds Road in Killeen as urban wildlife,
- A cow or two in the creek on occasion near Station 11905 at Backstorm Crossing,
- Swallow nests under the bridge at Station 21437 of Little Nolan Creek off US 190, and
- Ducks and geese in the creek near Station 14237 off SH93 in Belton.

No signs of feral hogs, such as scat or hog wallows, have been observed at or near the monitoring locations, although feral hogs have been indicated by at least one stakeholder as a problem along North Nolan Creek. Small trash, primarily paper and plastic items, has been observed along the stream banks at all monitoring stations. In addition at Station 11911 off FM 3219, large trash, including a mattress and a refrigerator, have been noted near but not in the creek. Although a "No Dumping" sign is posted near Station 11911, this appears to be a location where frequent dumping occurs.

While the stakeholder feedback and visual assessment provide an indication of sources, they do not necessarily reflect conditions of the watershed as a whole or the relative contribution of these sources. More details characterizing the watershed as a whole are provided in the forthcoming sections with regard land use, point and nonpoint sources, and preliminary indications from monitoring data. Future tasks in this project will address the relative contribution of various identified sources.

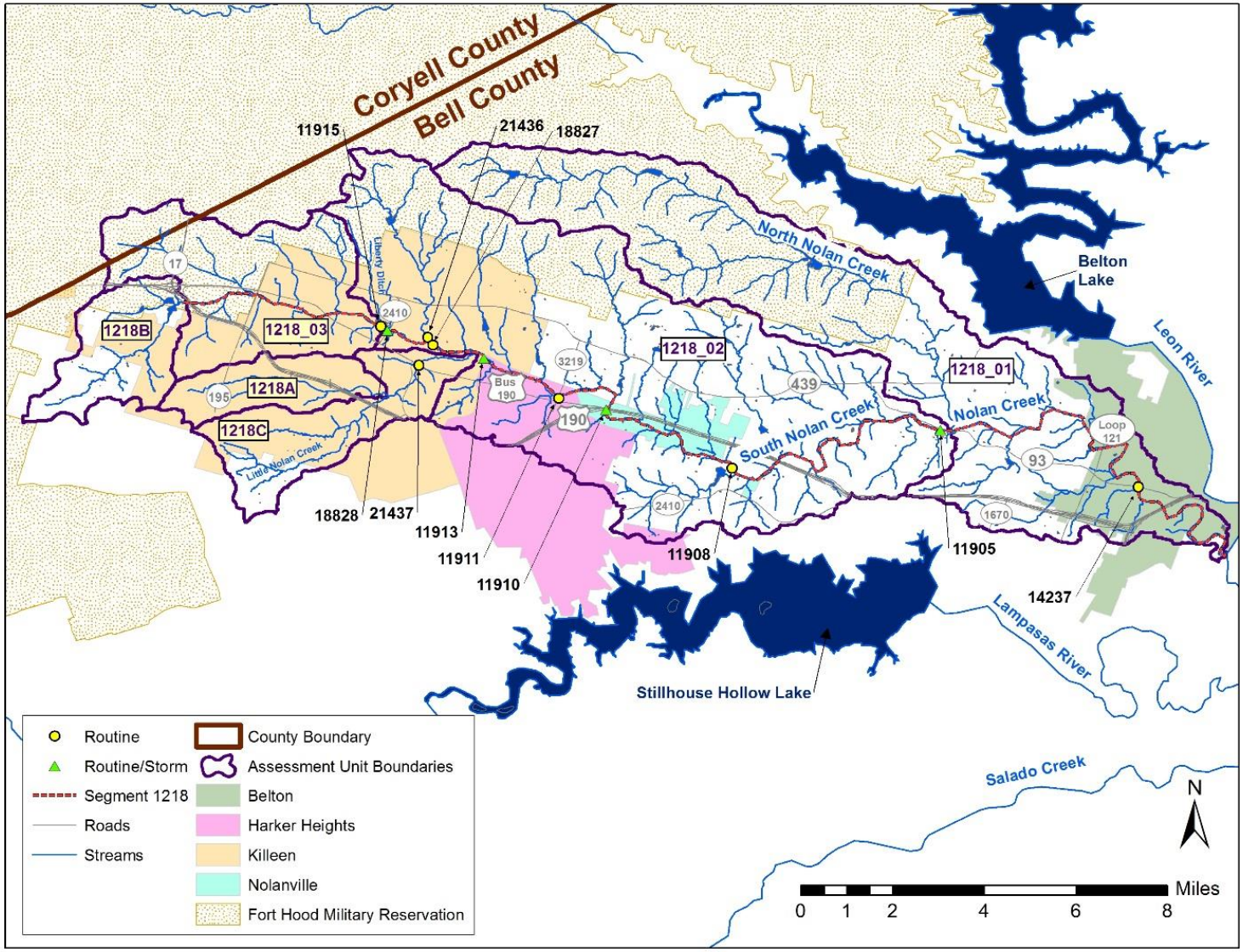

Figure 2-1 Project monitoring locations in the Nolan Creek/South Nolan Creek watershed.

SECTION 3

Land Use

Land use/land cover data were obtained from the 2011 National Land Cover Database. The 2011 National Land Cover Database applies a 30 meter spatial resolution and is based on circa 2011 Landsat satellite data (USGS, 2014). The land use classification descriptions from the National Land Cover Database representing the watershed area are defined as follows:

Open Water – areas of open water, generally with less than 25% cover of vegetation or soil.

Developed – areas with a mixture of some constructed materials and vegetation with impervious surfaces ranging from 20% to 100% of the total area. Subcategories of developed, which were combined in Table 3-1 and Figure 3-1, include:

- Developed, Open Space – areas with a mixture of some constructed materials, but mostly vegetation in the form of lawn grasses. Impervious surfaces account for less than 20% of total cover. These areas most commonly include large-lot single-family housing units, parks, golf courses, and vegetation planted in developed settings for recreation, erosion control, or aesthetic purposes.
- Developed, Low Intensity – areas with a mixture of constructed materials and vegetation. Impervious surfaces account for 20% to 49% percent of total cover. These areas most commonly include single-family housing units.
- Developed, Medium Intensity – areas with a mixture of constructed materials and vegetation. Impervious surfaces account for 50% to 79% of the total cover. These areas most commonly include single-family housing units.
- Developed High Intensity – highly developed areas where people reside or work in high numbers. Examples include apartment complexes, row houses and commercial/industrial. Impervious surfaces account for 80% to 100% of the total cover.

Barren Land – areas of bedrock, desert pavement, scarps, talus, slides, volcanic material, glacial debris, sand dunes, strip mines, gravel pits and other accumulations of earthen material. Generally, vegetation accounts for less than 15% of total cover.

Forest – areas dominated by trees generally greater than 5 meters tall, and greater than 20% of total vegetation cover. Subcategories of forest, which were combined in Table 3-1 and Figure 3-1, include:

- Deciduous Forest – areas dominated by trees generally greater than 5 meters tall, and greater than 20% of total vegetation cover. More than 75% of the tree species shed foliage simultaneously in response to seasonal change.
- Evergreen Forest – areas dominated by trees generally greater than 5 meters tall, and greater than 20% of total vegetation cover. More than 75% of the tree species maintain their leaves all year. Canopy is never without green foliage.

- Mixed Forest – areas dominated by trees generally greater than 5 meters tall, and greater than 20% of total vegetation cover. Neither deciduous nor evergreen species are greater than 75% of total tree cover.

Shrub/Scrub – areas dominated by shrubs; less than 5 meters tall with shrub canopy typically greater than 20% of total vegetation. This class includes true shrubs, young trees in an early successional stage or trees stunted from environmental conditions.

Grassland/Herbaceous – areas dominated by gramanoid or herbaceous vegetation, generally greater than 80% of total vegetation. These areas are not subject to intensive management such as tilling, but can be utilized for grazing.

Pasture/Hay – areas of grasses, legumes, or grass-legume mixtures planted for livestock grazing or the production of seed or hay crops, typically on a perennial cycle. Pasture/hay vegetation accounts for greater than 20% of total vegetation.

Cultivated Crops – areas used for the production of annual crops, such as corn, soybeans, vegetables, tobacco, and cotton, and also perennial woody crops such as orchards and vineyards. Crop vegetation accounts for greater than 20% of total vegetation. This class also includes all land being actively tilled.

Wetlands – areas where the soil or substrate is periodically saturated with or covered with water. Subcategories, which were combined in Table 3-1 and Figure 3-1, include:

- Woody Wetlands – areas where forest or shrubland vegetation accounts for greater than 20% of vegetative cover and the soil or substrate is periodically saturated with or covered with water.
- Emergent Herbaceous Wetlands – Areas where perennial herbaceous vegetation accounts for greater than 80% of vegetative cover and the soil or substrate is periodically saturated with or covered with water.

Because county level data are often used in assessing potential pollution sources within watersheds, such as livestock numbers (see Teague et al., 2009), land use for the Nolan Creek/South Nolan Creek watershed was compared to that of Bell County. While situated primarily within Bell County, the land use of the Nolan Creek/South Nolan Creek watershed varies greatly from the county with a much larger portion of the watershed associated with urban land (Figure 3-1 and Table 3-1). Because developed land is dominant, this category is also presented by subcategory within AUs (Figure 3-2). The land use/land cover associated with each AU varies greatly with developed land representing more than 75 percent of the land area in AUs 1218_03, 1218A, 1218B, and 1218C (Table 3-3). In AU 1218_02, developed land covers about a third of the land area with grassland/herbaceous and forest combined representing over half. In AU 1218_01, forest is even more dominant, particularly along the watershed area of North Nolan Creek with grassland/herbaceous and developed areas as less prominent land use/land covers.

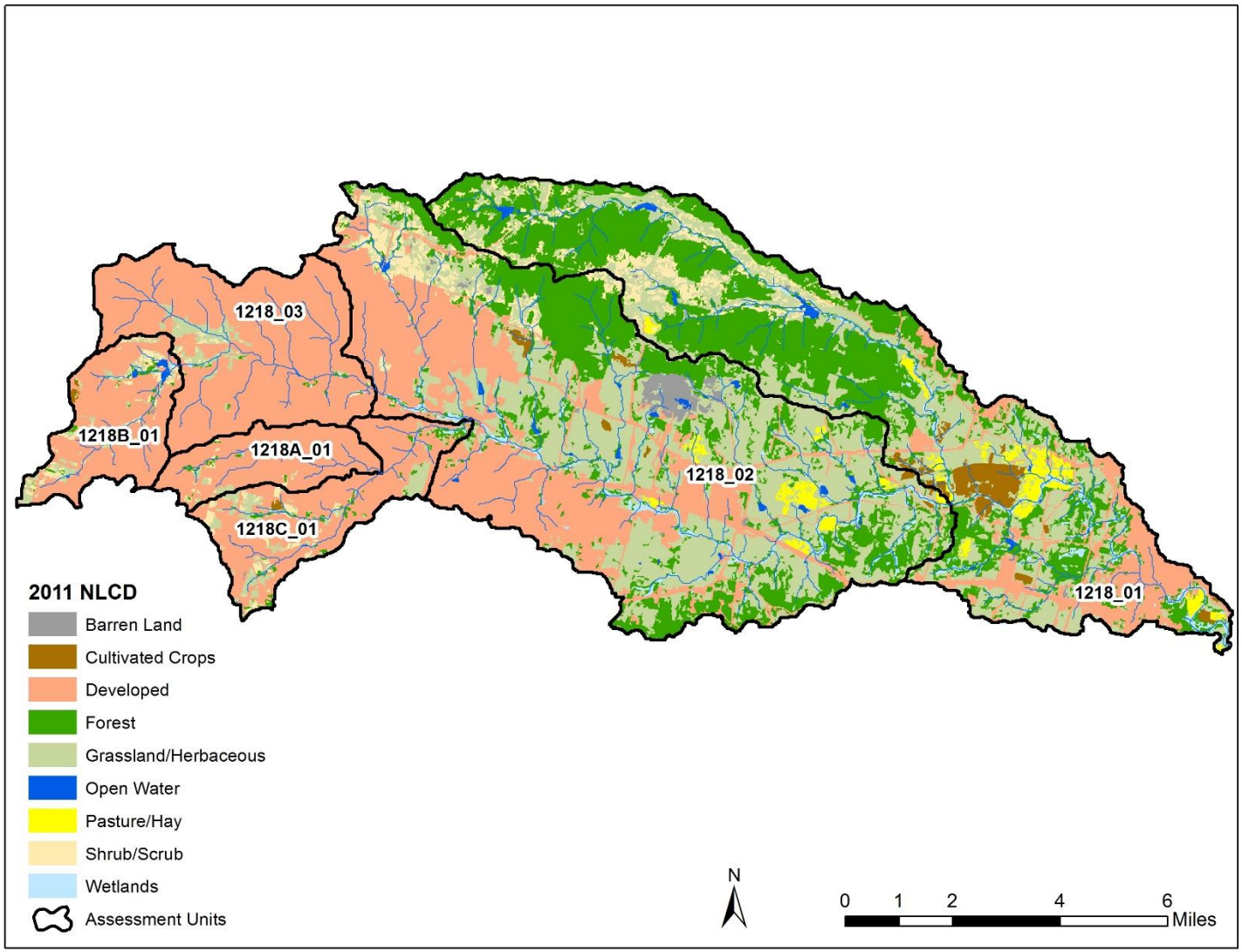

Figure 3-1 Land use/land cover for the Nolan Creek/South Nolan Creek watershed. Source: 2011 National Land Cover Database (USGS, 2014).

Table 3-1 Comparison of land use/land cover for the Nolan Creek/South Nolan Creek watershed with Bell County. Source: 2011 National Land Cover Database (USGS, 2014).

Category	Nolan Creek/South Nolan Creek Watershed (%)	Nolan Creek/South Nolan Creek Watershed (acres)	Bell County (%)	Bell County (acres)
Developed	40.1	29,196	13.3	92,480
Barren	0.8	590	0.3	2,086
Forest	22.6	16,708	17.5	121,684
Shrub/Scrub	4.2	3,040	4.3	29,899
Grassland Herbaceous	26.8	19,517	32.0	222,508
Pasture Hay	1.5	1,072	7.5	52,150
Cultivated Crops	1.4	991	19.0	132,114
Wetlands	1.8	1,337	2.9	20,165
Open Water	0.5	360	3.2	22,251
Totals	100.0	72,811	100.0	695,336

By subcategory for developed land (Table 3-4), open space represented most of the developed land in AU 1218_01. Inspection of several of these open space developed areas within AU 1218_01 using Google maps indicated a few large rural subdivisions outside the City of Belton and several parks and large-lot subdivisions within Belton. The high intensity developed area within AU 1218_01 largely corresponded with the downtown area of Belton off Central and E 2nd Ave between N Pear St and Blair St, which has many large buildings with large paved areas for parking lots. Within AU 1218_02, there were similar findings with shopping areas in Harker Heights and Killeen representing high intensity developed areas as well as the air field on Fort Hood. Open areas corresponded with a golf course, parks, and areas with only a few buildings and very limited paved area. While not considered developed land of note within AU 1218_02 is a large area of barren land. While representing less than 2 percent of the area within AU 1218_02, much of this barren land is associated with a limestone quarry just north of the City of Nolanville (Figure 3-1). Within AU 1218_03, the downtown area of Killeen as represented between N. College and 10th St and Rancier Ave and W. Veterans Memorial Blvd as well as shopping areas on S. Fort Hood St were high intensity developed areas. Paved areas within Fort Hood were also noted as high intensity developed. In general, the medium to low intensity developed areas throughout the watershed appeared to correspond with housing density.

Table 3-2 Land area of each AU within the Nolan Creek/South Nolan Creek watershed.

AU	Acres	Percent
1218_01	23,317	32%
1218_02	30,902	42%
1218_03	7,998	11%
1218A	2,579	4%
1218B	3,589	5%
1218C	4,428	6%
Total	72,811	100%

Table 3-3 Land use/land cover by AU within the Nolan Creek/South Nolan Creek watershed. Source: 2011 National Land Cover Database (USGS, 2014).

Land Use/Land Cover Category	1218_01	1218_02	1218_03	1218A	1218B	1218C
Barren Land	0.1%	1.8%	0.0%	0.0%	0.1%	0.3%
Cultivated Crops	3.3%	0.5%	0.0%	0.0%	0.7%	0.5%
Developed	13.3%	32.1%	93.6%	94.2%	79.9%	76.6%
Forest	41.9%	21.4%	0.4%	1.3%	1.9%	4.2%
Grassland/Herbaceous	29.3%	36.8%	5.0%	2.5%	8.2%	12.0%
Open Water	0.6%	0.5%	0.0%	0.0%	1.2%	0.0%
Pasture/Hay	2.9%	1.3%	0.0%	0.0%	0.0%	0.0%
Shrub/Scrub	5.9%	3.3%	0.8%	1.9%	7.7%	5.9%
Wetlands	2.6%	2.2%	0.1%	0.1%	0.3%	0.5%

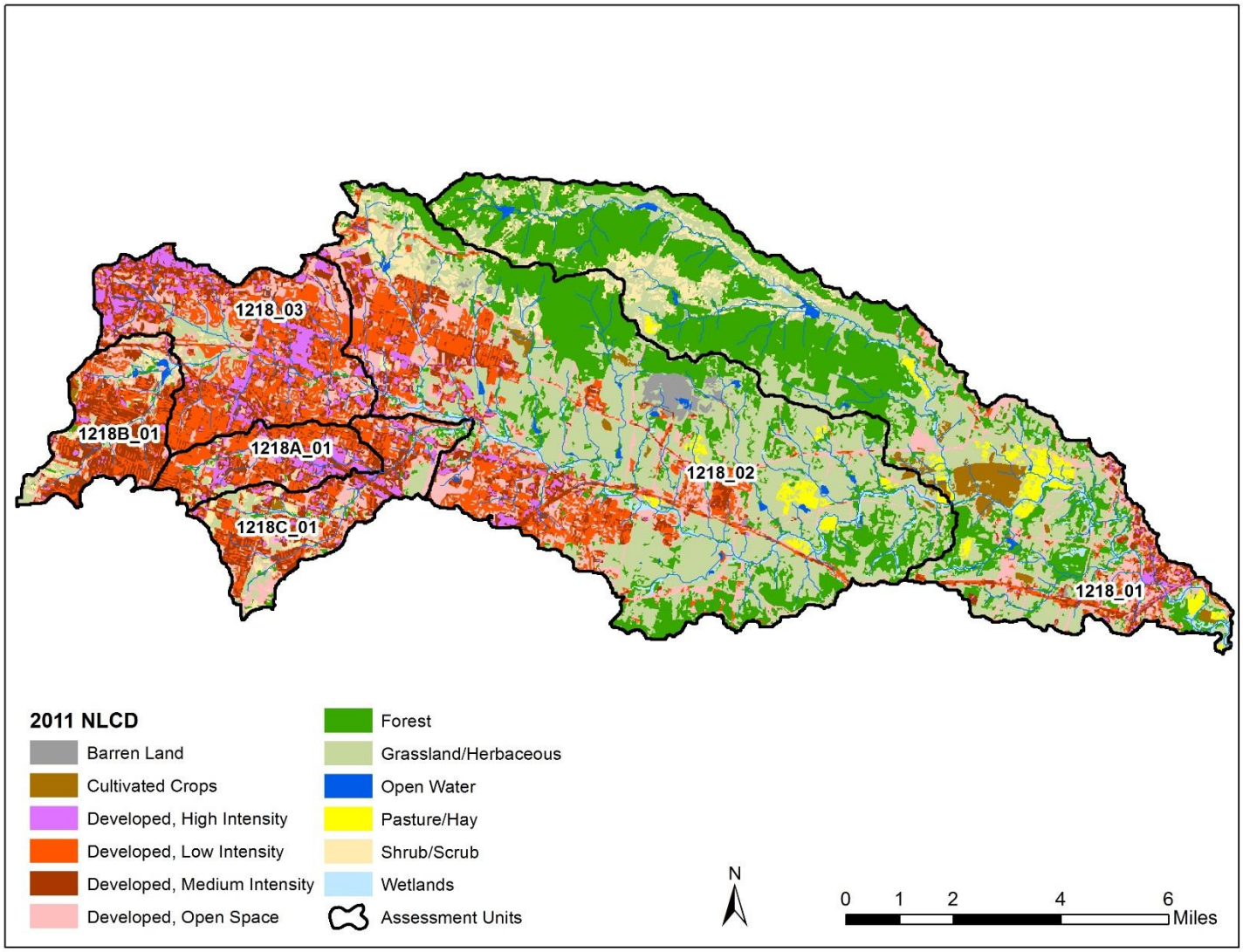

Figure 3-2 Land use/land cover for the Nolan Creek/South Nolan Creek watershed showing developed subcategories. Source: 2011 National Land Cover Database (USGS, 2014).

Table 3-4 Percent developed land by subcategory and number of total acres of developed land within each AU of the Nolan Creek/South Nolan Creek watershed. Source: 2011 National Land Cover Database (USGS, 2014).

Developed Subcategory	1218_01	1218_02	1218_03	1218A	1218B	1218C
Developed, High Intensity	6%	6%	17%	18%	4%	8%
Developed, Medium Intensity	18%	18%	24%	30%	43%	32%
Developed, Low Intensity	19%	37%	36%	37%	34%	30%
Developed, Open Space	57%	39%	22%	15%	20%	30%
Total Acres Developed	**3,106**	**9,913**	**7,488**	**2,430**	**2,867**	**3,391**

SECTION 4

Potential Pollutant Sources

Regulated Sources

Potential sources of bacteria and other sources of pollution can be divided into two general categories: regulated and non-regulated. Pollution sources that are regulated have permits issued by TCEQ under the Texas Pollutant Discharge Elimination System (TPDES) as part of the National Pollutant Discharge Elimination System (NPDES) under Environmental Protection Agency (EPA). Examples of regulated point sources include wastewater treatment facility (WWTF) discharges, stormwater discharges associated with municipal separate storm sewer systems (MS4s), and concentrated animal feeding operations (CAFOs). These various regulated sources are required to have either an individual permit that is facility specific or operate under a general permit.

Wastewater Permits

There are eight permitted outfalls that discharge within the Nolan Creek/South Nolan Creek watershed (Figure 4-1 and Table 4-1). Of note, the Bell Count Water Control and Improvement District (WCID) No. 1 - Plant 3 facility, also known as the "South Plant", is physically located south of the watershed on 8290 Chaparral Road in Killeen, but discharges to South Nolan Creek within the City of Nolanville. Managers at the WCID No. 1 - Plant 3 have indicated that if approved as part of an upcoming permit renewal, portions of the wastewater from this plant may be discharged to Trimmier Creek, outside the Nolan Creek/South Nolan Creek watershed, but emphasized that this potential change has not yet been approved. Bell County WCID No. 1 also runs a composting facility, which is located outside the watershed boundary, but processes biosolids from all three of its WWTFs.

A review of on-line permit enforcement actions conducted in December 2014 indicated the following:

- For Temple Belton Regional WWTF (Permit No. WQ0011318001), no enforcement actions were documented.

- For Bell County WCID No. 3 WWTP (Permit No. WQ0010797001), two enforcement actions were indicated.

    - The first dated May 28, 1997, for noncompliance with daily average total suspended solids concentrations (limit 15 mg/L) based on four exceedance noted in 1996.

    - The second dated November 5, 2003, dealt with excursions of the biochemical oxygen demand (BOD) limit of 10 mg/L, which had been exceeded on several occasions between December 2001 and January 2003.

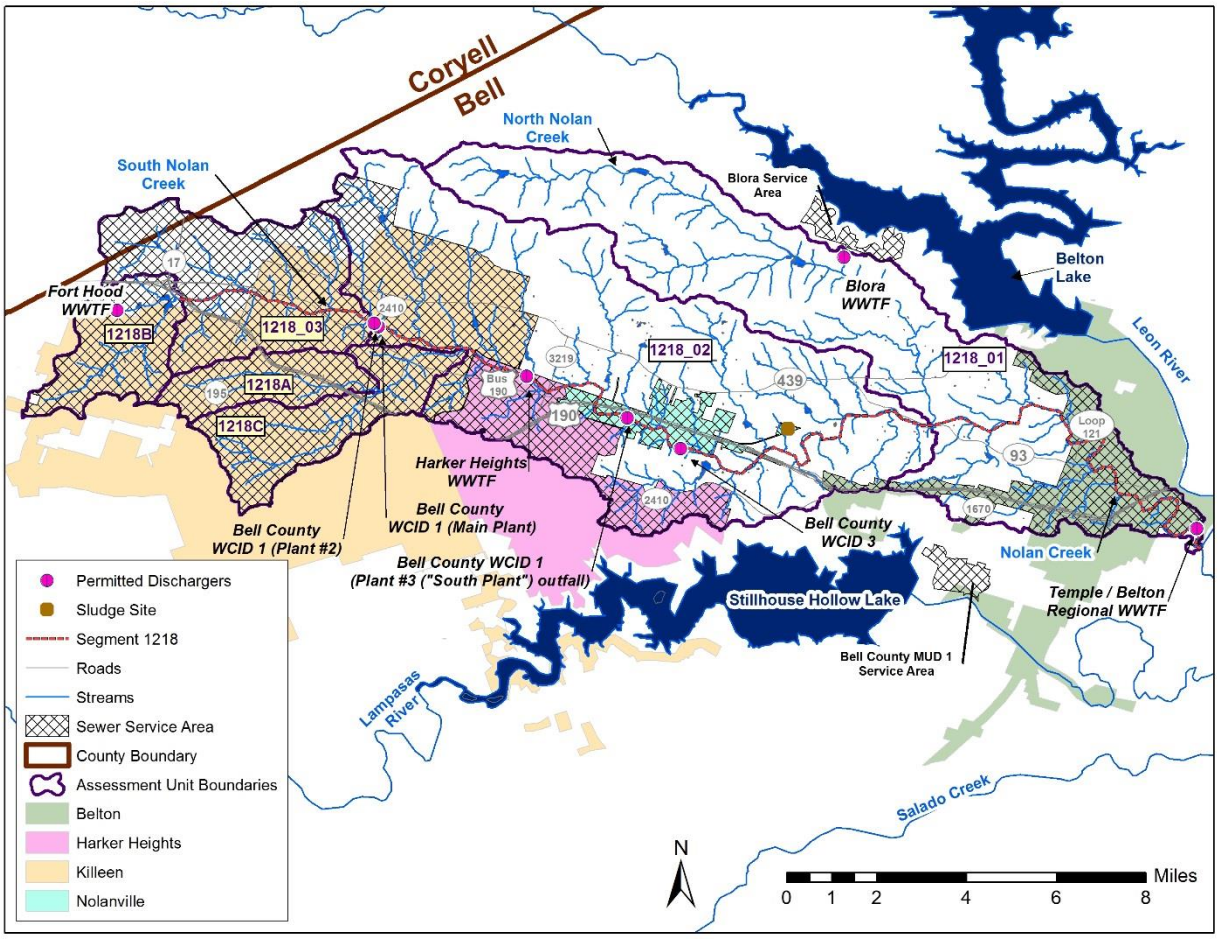

Figure 4-1 Location of permitted discharges and service areas within the Nolan Creek/South Nolan Creek watershed. Note: The service area for some dischargers extends outside the watershed boundaries, largely following municipal boundaries for the cities of Killeen and Harker Heights. Location of permitted wastewater outfalls from TCEQ GIS layer, publication date March 12, 2014.

- For City of Harker Heights WWTF (Permit No. WQ0010155001), two enforcement actions were indicated.
    - The first dated November 2, 2011, for grease blockage in the collection system that caused about 28,800 gallons of wastewater to discharge from two manholes and a septic tank. This discharge flowed into an unnamed tributary of Stillhouse Hollow Lake, thus, did not impact Nolan Creek/South Nolan Creek.
    - The second was active with a Docket Number 2014-1276-MWD-E issued September 2, 2014, but no further action or information was currently available.
- For Bell County WCID No. 1 WWTF (Main Plant, Permit No. WQ0010351002), no enforcement actions were indicated, although a complaint was documented regarding failure to notify the news media of a spill, which commenced on February 4, 2006.

Table 4-1 Permitted WWTF within the Nolan Creek/South Nolan Creek watershed Source: Central Registry TCEQ (2014a).

Facility Name	Facility Location	Latitude	Longitude	EPA ID	Permit #	Permitted Discharge (MGD)
Temple Belton Regional WWTF	Belton, TX	31.0432930	-97.4386970	TX0058378	WQ0011318001	10
Bell County WCID No. 3 WWTF	Nolanville, TX	31.0690260	-97.6050450	TX0069191	WQ0010797001	0.675
City of Harker Heights WWTF	Harker Heights, TX	31.0923330	-97.6546730	TX0024473	WQ0010155001	3
Bell County WCID No. 1 WWTF (Main Plant)	Killeen, TX	31.1082780	-97.7025070	TX0024597	WQ0010351002	18
Bell County WCID No. 1 (Plant 2)	Killeen, TX	31.1093070	-97.7037850	TX0102938	WQ0010351003	6
Bell County WCID No. 1 (Plant 3, South Plant)	Killeen, TX	31.0788370	-97.622790	TX0125377	WQ0014387001	6
Universal Services Ft Hood WWTF	Ft Hood, TX	31.1135080	-97.7866860	TX0101869	WQ0013358001	0.09
Blora WWTF	Ft Hood, TX	31.1305167	-97.5523898	TX0132446	WQ0014994001	0.03

- For Bell County WCID No. 1 WWTF (Plant No. 2, Permit No. WQ0010351003), three enforcement actions were listed.
    - The first has a Docket Number 1999-0770-MWD-E, but no activity or action was indicated.
    - The second was dated September 15, 2004 and lists several compliance issues. Many of these compliance issues were found during an investigation that occurred on May 1, 2003 in response to an unauthorized discharge of sludge to Nolan Creek/South Nolan Creek that resulted in a fish kill of about 28 fish documented on April 15, 2003.

  - The third enforcement action was dated March 23, 2005 and notes a failure to comply with effluent limitations on one or two occasions in 2003 or 2004 for daily maximum TSS (limit 40 mg/L), daily maximum carbonaceous biochemical demand (limit 25 mg/L), daily average ammonia-nitrogen (limit 2 mg/L), daily average loading ammonia-nitrogen (limit 100 lbs/day), and daily maximum ammonia-nitrogen (limit 10 mg/L).

- For Bell County WCID No. 1 (Plant 3, South Plant; Permit No. WQ0014387001), no enforcement actions were documented.

- For Universal Services Ft Hood WWTF (Permit No. WQ0013358001), no enforcement actions were documented.

- For Blora WWTF (Permit No. WQ0014994001), no enforcement actions were documented.

Monthly reporting data were downloaded from the EPA ECHO (Enforcement and Compliance History Online) website (http://echo.epa.gov/?redirect=echo) that covered data from December 2009 through June 2014. Not all WWTFs had bacteria data reported, but a general summary indicates that except on a few occasions, bacteria concentrations were well below water quality criteria limits of 126 cfu/100 mL (Table 4-2).

Stakeholders have indicated that sanitary sewer overflows (SSOs) are an issue in the watershed. Sewer lines that transport untreated sewage to WWTFs can lead to unauthorized discharges or SSOs when pipes overflow through a manhole, cleanout, or broken pipe. Water Quality Noncompliance Notifications to TCEQ and news reports note SSOs have occurred on occasion and continue to occur throughout the watershed. On most occasions, these SSOs are contained and raw sewage cleaned up with vacuum trucks to limit its impact on waterways (Ramirez, 2014).

The following examples indicate some of the issues with sewer lines and wastewater treatment systems that could impact water quality within Nolan Creek/South Nolan Creek. A sewage spill in February 2011 of almost 300,000 gallons resulted in a fish kill investigated by Texas Parks and Wildlife Department (TPWD) (Scott, 2011). A SSO occurred in Harker Heights in September 2010 after two days of extreme flooding associated with Tropical Storm Hermine leading to about 430,000 gallons of raw sewage spilling into South Nolan Creek (KXXV-TX News, 2010). While not resulting in a spill, stormwater from an October 2013 event transported an oak tree that cracked a concrete block encasing an aerial sewer line running over the creek within the City of Nolanville (Lynch, 2013). As of January 2014, this damaged sewer line was still not leaking but was considered a “ticking time bomb” as funding efforts for replacement were pursued (Griffin, 2014).

Table 4-2 Reported flow and *E. coli* data for WWTFs within the Nolan Creek/South Nolan Creek watershed Source: EPA ECHO website, data downloaded December 11, 2014.

Facility Name	Permit #	Data Range	Measured Discharge (MGD)	*E. coli* excluding excursions	Number of Obs.	Number of *E. coli* Excursions	Details of *E. coli* Excursions
Temple Belton Regional WWTF	WQ0011318001	Dec2009-Jun2014	6.42	All ≤ 9 cfu/100 mL	55	2	Jun2010 = 117 cfu/100 mL, Feb2010 = 235 cfu/100 mL
Bell County WCID No. 3 WWTF	WQ0010797001	Dec2009-Jun2014	0.315	No *E. coli* data reported	0	0	No *E. coli* data reported
City of Harker Heights WWTF	WQ0010155001	Dec2009-Jun2014	1.95	All ≤ 25 cfu/100 mL	55	None	No excursions
Bell County WCID No. 1 WWTF (Main Plant)	WQ0010351002	Dec2009-Jun2014	11.3	Median 20 cfu/100 mL	55	3	Sep2010 = 127 cfu/100 mL, Aug2013 = 127 cfu/100 mL, Sep2013 = 233 cfu/100 mL
Bell County WCID No. 1 (Plant 2)	WQ0010351003	Dec2009-Jun2014	Operation Shutdown	Operation Shutdown	0	0	Operation Shutdown
Bell County WCID No. 1 (Plant 3, South Plant)	WQ0014387001	Dec2009-Jun2014	2.75	Median 1 cfu/100 mL, all ≤ 35 cfu/100 mL	55	0	No excursions
Universal Services Ft Hood WWTF	WQ0013358001	Oct2013-Apr2014	0.048	All ≤ 1 cfu/100 mL	3	None	No excursions
Blora WWTF	WQ0014994001	Sep2011-Jun2014	0.011	All ≤ 3 cfu/100 mL	12	None	No excursions

In 2009, a breakdown of the WWTF occurred at WCID No. 1 - Plant 3 due to high levels of grease, fats, and oils leading to the need for new diffusors (Chen, 2010). As a result of these high grease levels at the WCID No. 1 - Plant 3, the City of Killeen passed an ordinance that regulates fats, oils, and grease entering the City's sewer system (Killeen, Texas Code of Ordinances Part II, Article III Sewers and Sewage Disposal, Division 3. Fat, Oil and Grease Control and Prevention) and recently revised this ordinance decreasing water temperatures for local food service from 150ºF to 120ºF to better allow trapping of grease, thus, better protecting the sewage collection system and treatment plants from damage (Stewart, 2014). Such ordinances and enforcement of them is an important part of controlling SSOs, which not only release bacteria into the water, but can also cause fish kills.

While sporadic and difficult to predict, it will be important to consider the relative influence of SSO events on overall loadings of bacteria to Nolan Creek/South Nolan Creek as a potential contributing source. Grease clogging of sewer lines is considered an on-going problem in dealing with wastewater within the watershed (Janes, 2013). Many of the issues related to SSOs are addressed through the MS4 permitting process with regard to regulated stormwater, and when spills occur, there is a cleanup effort required, so not all that spills stays as a contributing source.

Regulated Stormwater

The TPDES and the NPDES MS4 Phase I and II rules require municipalities and certain other entities in urban areas to obtain permits for their stormwater systems. Phase I permits are individual permits for large and medium sized communities with populations of or exceeding 100,000 (based on 1990 U.S. Census data), whereas Phase II permits are for smaller communities that are located within an "Urbanized Area". An "Urbanized Area" is defined by the U.S. Census Bureau as an area with populations greater than 50,000 and with an overall population density of at least 1,000 people per square mile. Within the watershed area the following six entities have MS4 permits:

- Bell County – TXR040055
- Killeen – TXR040010
- Harker Heights – TXR040011
- Belton – TXR040351
- Fort Hood Family Housing LP – TXR040317
- Nolanville – TXR040175

For Phase II permits the jurisdictional area is defined as the intersection or overlapping areas of the city limits and the 2010 Census Urbanized Areas (Figure 4-2). For Bell County and Fort Hood, the MS4 area includes urbanized areas not associated with municipalities.

All six entities fall under the Phase II MS4 requirements and are permitted under the small MS4 TPDES General Permit (TXR040000) effective August 13, 2007. Of the six, Bell County and Fort Hood are considered non-traditional small MS4s in that these entities cannot pass ordinances nor have the enforcement capability of traditional small MS4s associated with cities. While the 2007 MS4 General Permit was issued for only five years and expired on August 12, 2012, a notice of intent to renew this general permit was published in the Texas Register on April 13, 2012, which allowed administrative continuance of coverage under the 2007 Small MS4

General Permit until issuance of a new general permit. On December 13, 2013, a new small MS4 General Permit was issued, at which time all regulated entities were given 180 days to apply for coverage or a waiver under this new general permit, thus, authorization status under the 2007 Small MS4 General Permit ended June 11, 2014. According to TCEQ on-line permit records as of November 3, 2014, all six regulated entities in the Nolan Creek/South Nolan Creek watershed, except Nolanville, had submitted a notice-of-intent to renew coverage under the new 2013 Small MS4 General Permit with a status of "pending". It is anticipated that these six regulated entities will have approved permits in the coming months and until so continue to function under the 2007 Small MS4 General Permit. A review of the MS4 permit status on July 3, 2015 indicated that all but Nolanville with active and approved permits through December 13, 2018.

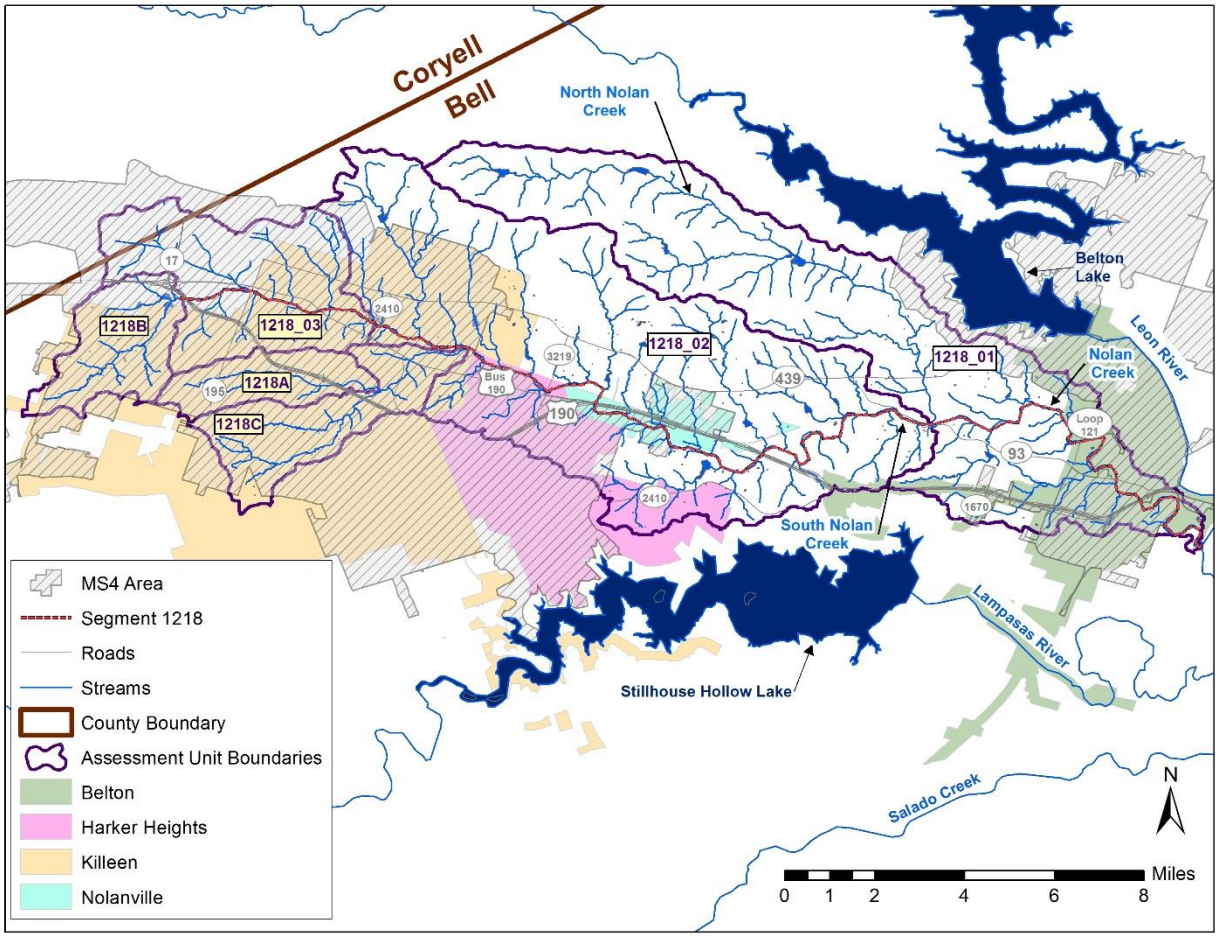

Figure 4-2 Location of MS4 areas within the Nolan Creek/South Nolan Creek watershed. Source: 2010 Census Data of urbanized areas.

CAFOs and Other Permitted Facilities

There are no permitted concentrated animal feeding operations (CAFOs) within the Nolan Creek/South Nolan Creek watershed.

There is an active permit (WQ000445800) for the beneficial land application of sewage sludge and domestic septage for the Grandy Ranch located about 1.2 miles east of the intersection of U.S. Highway 190 and Paddy Hamilton Road (see Figure 4-1). The permit covers a land application site of about 368 acres with an application rate not to exceed 2.61 dry tons per acre per year of sewage sludge and 3,692.3 gallons per acre per year domestic septage.

Non-Regulated Sources

Non-regulated sources are not regulated by permit under the TPDES. Non-regulated sources of bacteria include waste from livestock, wildlife, pets, and failing on-site sewage facilities (OSSFs).

Livestock

While no CAFOs exist in the watershed, livestock are present in the rural areas. Even within Fort Hood, grazing is allowed in some locations. Specific watershed level information regarding the number of grazing livestock is unavailable, but county level statistics are available for the United States Department (USDA). The latest USDA Census of Agriculture conducted by the National Agriculture Statistics Service (NASS) in 2012 notes cattle followed by goats and sheep as the dominant livestock types for Bell County (USDA-NASS, 2014). Horses and ponies combined with estimates of mules, burros, and donkeys are also considered prominent livestock categories (Table 4-3). Poultry, while noted as a major livestock category within Bell County with almost 14,000 chickens, primarily layers, was excluded as a category for the Nolan Creek/South Nolan Creek watershed, because no poultry houses are located within the watershed area. Hogs and pigs were also excluded as there are no large hog facilities within the watershed. Because the land use for Bell County overall is quite different from the land use within the Nolan Creek/South Nolan Creek watershed (see Table 3-1), livestock numbers for Bell County were weighted based on the land covers most often associated with each to determine an estimate of livestock numbers within the Nolan Creek/South Nolan Creek watershed (Table 4-4).

Cropland

Cropland is generally not considered a source of bacteria unless organic fertilizer is applied, but discussion with Natural Resources Conservation Service (NRCS) personnel indicate that cropland at times can be a bacteria source depending on the animals residing within the cropland area. Feral hogs, deer, and even birds, can potentially contribute to bacteria from cropland areas. More often, cropland is considered a source of nutrients in runoff from fertilizer whether organic or inorganic.

Table 4-3 Livestock census estimates for Bell County. Source: USDA-NASS (2014).

Category	Bell County Total Inventory Number
Cattle & Calves	34,922
All Poultry	13,898
All Goats	12,813
Sheep & Lambs	4,269
Horses & Ponies	2,903
Mules, Burros, & Donkeys	832
Hogs & Pigs	750

Table 4-4 Livestock estimates for the Nolan Creek/South Nolan Creek watershed. Based on 2012 Census of Agriculture for Bell County (USDA-NASS, 2014) and 2011 NLCD (USGS, 2014).

Category	Estimated Animals in Bell County	Associated Land Use/Land Cover (LULC)	Land Area in Bell County represented by LULC (acres)	Land Area in Nolan Creek/South Nolan Creek Watershed associated with LULC (acres)	Estimated Animals in Nolan Creek/South Nolan Creek Watershed
Cattle & Calves	34,922	Grassland Herbaceous & Pasture Hay	274,658	20,589	2,618
Sheep & Goats	17,082	Grassland Herbaceous, Pasture Hay, Shrubland & Forest	396,342	37,297	1,607
Horses & Ponies and Mules, Burros, & Donkeys	3,735	Grassland Herbaceous & Pasture Hay	274,658	20,589	280

Within the Nolan Creek/South Nolan Creek watershed, soil survey information indicates that there is limited land suitable for cropland (Huckabee et al., 1977). The land use/land cover layer supports this assertion indicating only 1.4 percent of the watershed as cropland with the majority of the cropland area laying just to the east within the Nolan Creek watershed past the convergence of South Nolan Creek with North Nolan Creek (Figure 2-1). Cultivated crops in this area are primarily oats, winter wheat, and corn.

Improved pasture used for hay or grazing may also receive fertilizer, thus being a potential source of nutrients in runoff and bacteria if manure is applied as fertilizer. Improved pastures are also often used for grazing livestock with manure deposition on the land, thus, providing a potential source of bacteria via runoff. Similar to cultivated cropland, only 1.5 percent of the watershed is classified as pasture/hay, thus, likely a limited source of nonpoint source nutrients and bacteria.

As there are no CAFOs in the watershed, there are no documented animal waste application fields.

Wildlife and Feral Animals

While smaller wildlife, such as raccoons and opossums, have adapted to rural and urban settings, deer are more likely found in the range and woodland areas (Figure 3-1). The Speck-Tarrant-Purves soil association found largely along North Nolan Creek and Nolan Creek supports range and woodland and is in noted in the Bell County Soil Survey as good wildlife habitat (Huckabee et al., 1977). According to Texas Parks and Wildlife Department (TPWD, 2012), the Nolan Creek/South Nolan Creek watershed falls into Resource Management Unit 23 of the Cross Timbers ecoregion and survey estimates as of 2011 indicate about 81 deer/1,000 acres or 12.3 acres per deer for this ecoregion where appropriate habitat occurs.

Feral hogs, while not natural wildlife, are invasive, unmanaged animals that are found throughout Texas and can contribute bacteria to streams in a manner similar to native wildlife. Feral hogs are classified by TPWD as unprotected, exotic, non-game animals. Feral hogs are noted for moving in groups along waterways. Particularly in times of drought, feral hogs will congregate near perennial water sources to drink and wallow (Taylor, 2003). While not typically found in urban areas, in rural areas of Texas hog densities have been estimated to range from 25 to 54 acres per hog (Borel et al., 2012).

On-Site Sewage Facilities

On-site sewage facilities (OSSFs) are often referred to as septic systems. These small waste management systems are generally associated with houses that are unable to connect to a central wastewater collection system. Septic systems are often used in rural areas, but may also exist in urban areas when subdivisions develop outside the area serviced by a centralized waste management system or when areas are annexed that have OSSFs that have not yet connected to a city's central waste management system. Within the Nolan Creek/South Nolan Creek watershed, the Bell County Health District deals with permitting of all new OSSFs. While there is a tracking of new systems through the permitting process, older or "grandfathered" systems (generally prior to 1989) are difficult to track, because permits were not required for these. At this time, a

complete inventory of OSSFs within the watershed does not exit and available information for most of the watershed is not in a format that can easily be mapped. Some data on locations of OSSFs was made available by the City of Killeen as part of its Septic Tank Elimination Program (STEP) and the location of these is shown in Figure 4-3.

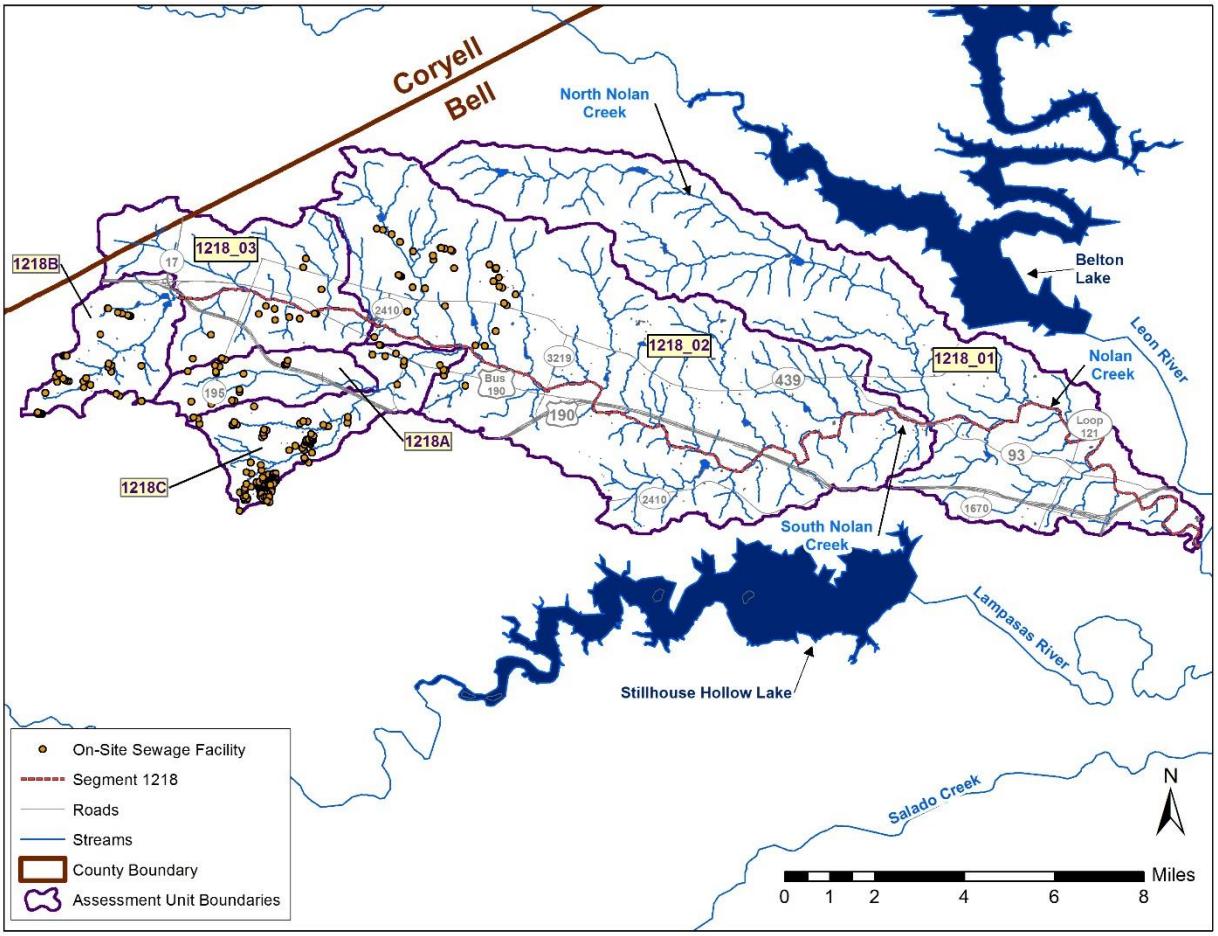

Figure 4-3 Location of some OSSFs within the Nolan Creek/South Nolan Creek watershed. Source: City of Killeen.

To identify areas not covered by a centralized collection system, the GIS layer associated with sewer service areas as identified in Figure 4-1 will be used. Masking out the area serviced by sewer systems, about 2,180 households exist in the Nolan Creek/South Nolan Creek watershed that are expected to be on OSSFs. This information in conjunction with the site-specific data provided by the City of Killeen will be used to determine the relative density of OSSFs within the watershed.

In the previous 319 study (Nett and Flowers, 2008), which focused on the upper third of the South Nolan Creek drainage area, the density of septic systems was found to be positively correlated with in-stream bacteria concentrations. When properly designed, installed, operated, and maintained, OSSFs can provide appropriate treatment of wastewater, but malfunctioning

system have been recognized to contribute significant loads of nutrients and bacteria, particularly if in close proximity to receiving water bodies (EPA, 2008). While the number of failing systems within the Nolan Creek/South Nolan Creek watershed is difficult to estimate, it is a recognized problem and steps are being taken in various areas to aid in resolving it. Of note, the City of Killeen started a Septic Tank Elimination Program (STEP) over 10 years ago, which aids homeowners in connecting to the City's sewer lines.

SECTION 5

Preliminary Indications from Water Quality Data

Relationships with flow or hydrologic conditions prior to the collection of water quality samples can aid in determining whether point or nonpoint sources are dominant in a system. Generally, when concentrations are higher at baseflow than in association with storm events, point sources are dominant. If concentrations increase with flow or in association with storm events, then nonpoint sources are likely dominant. Historical water quality data were downloaded from TCEQ's publically available online Surface Water Quality Monitoring Information System (SWQMIS; TCEQ, 2014b). Details regarding the available data are provided in the associated data inventory report for this project (see McFarland and Adams, 2015). As a preliminary review, historical water quality monitoring data were plotted by AU as flow versus parameter concentration for bacteria, nitrate, ortho-P, and total-P. These plots include all data in SWQMIS collected prior to May 2013. In May 2013, direct data collection started for this project, and a preliminary summary of those results will be presented separately.

For historical bacteria data, whether fecal coliform or *E. coli*, there appeared to be some increase in bacteria concentrations with flow, but there was also a lot of variability in this relationship (Figure 5-1, 5-2, and 5-3). Due to limited sample size or the high degree of variability in bacteria concentrations at a given flow, relationships between flow and bacteria were not considered to significantly increase or decrease. Particularly for AU 1218_02, there appeared to be a lot of noise or variability in fecal coliform concentrations at flows below 50 cfs (Figure 5-2).

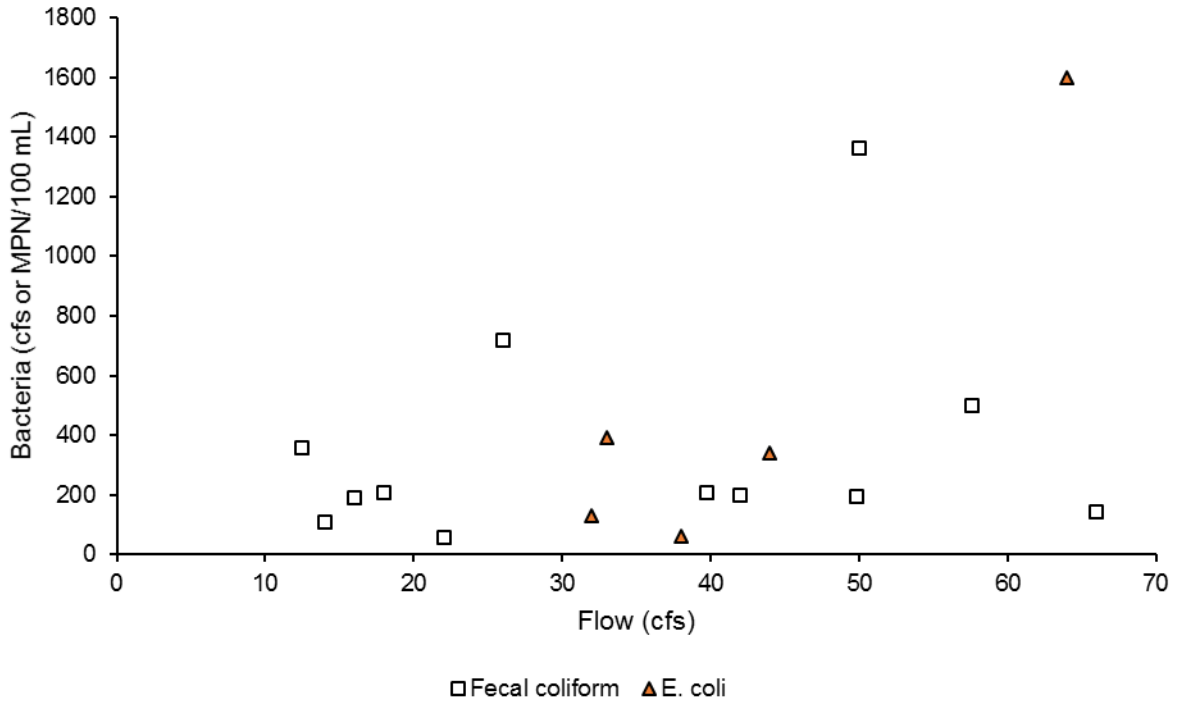

Figure 5-1 Flow versus bacteria concentrations for AU 1218_01.

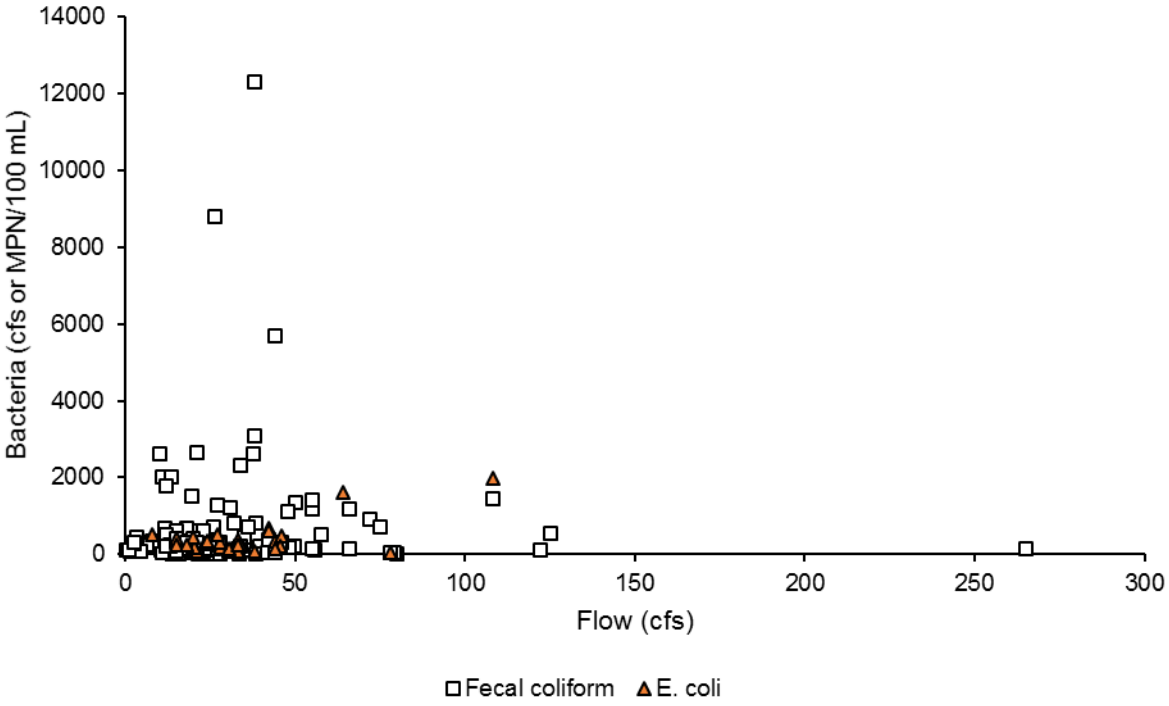

Figure 5-2 Flow versus bacteria concentrations for AU 1218_02.

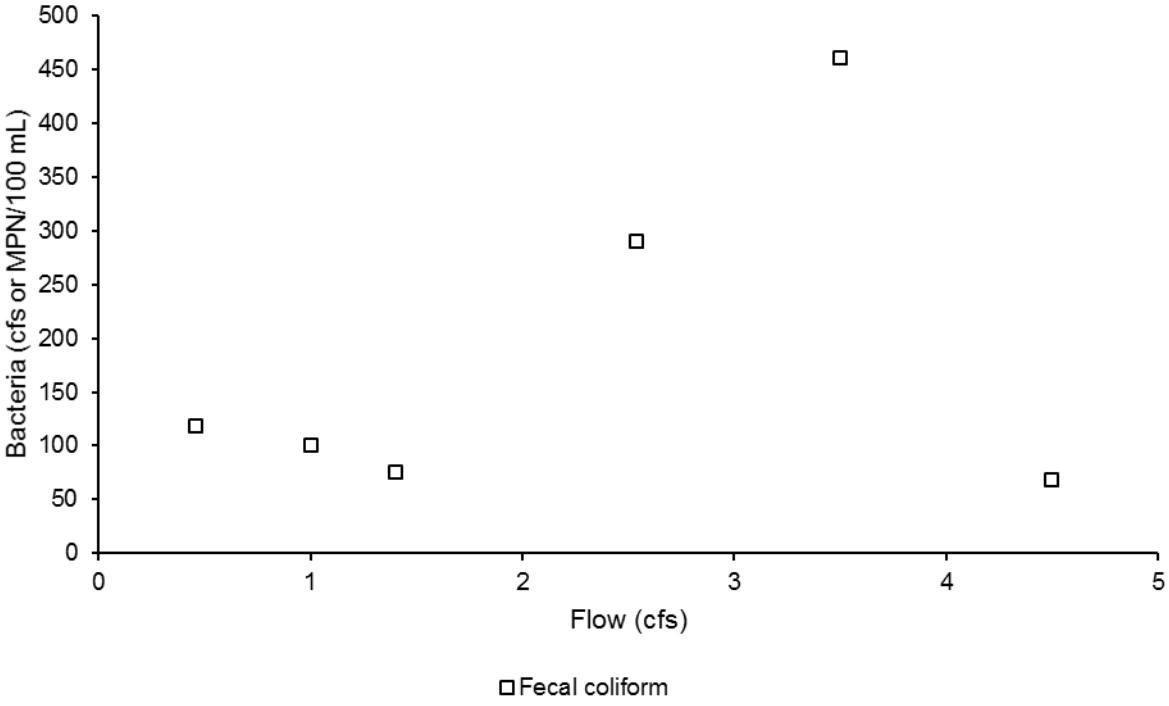

Figure 5-3 Flow versus bacteria concentrations for AU 1218_03.

In evaluating nitrate concentrations in relation to flow, there appeared to be a general trend of higher concentrations occurring at flows of 50 cfs or less for AUs 1218_01 and 1218_02, while AU 1218_03 only had a few paired values all occurring at relatively low flows with correspondingly low nitrate concentrations (Figure 5-4). Of note, no direct point sources discharge to South Nolan Creek within AU 1218_3, but several point source discharges occur along or above AUs 1218_01 and 1218_02. Decreasing nitrate concentrations with increasing flows may indicate primarily point source contributions of nitrates.

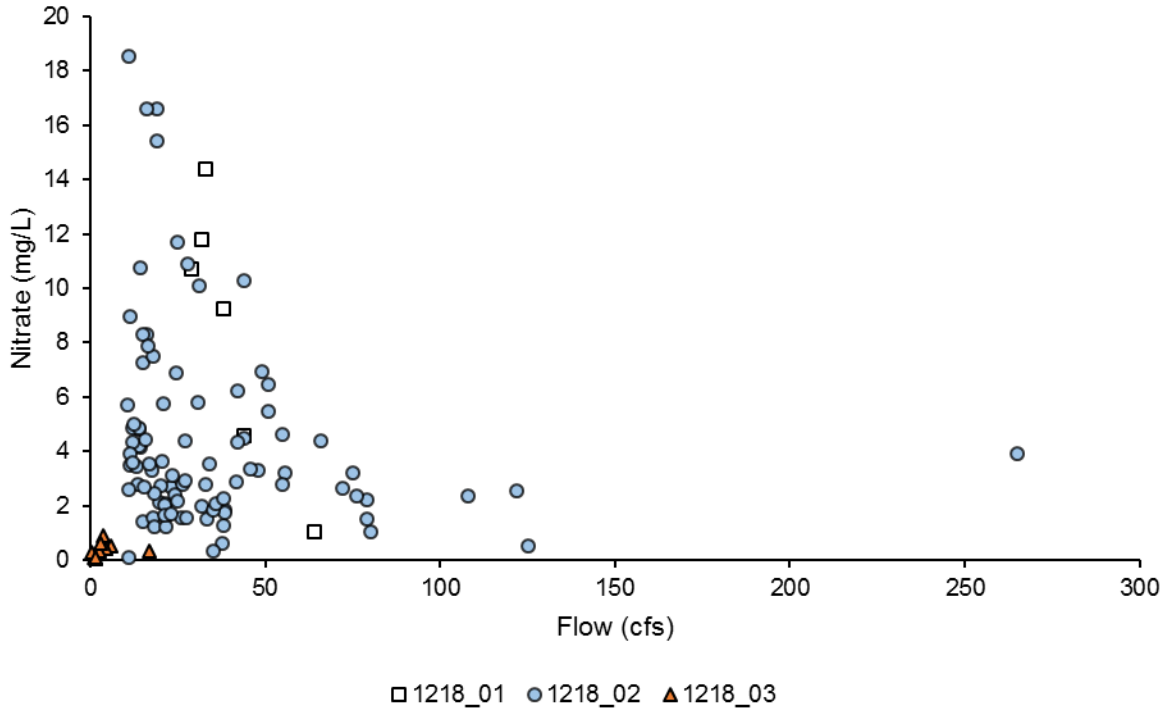

Figure 5-4 Flow versus nitrate concentrations by AU.

Phosphorus concentrations also appeared to decrease with increasing flows for both ortho-P and total-P for paired observations in AUs 1218_01 and 1218_03 (Figures 5-5 and 5-6). For AU 1218_03, only a few paired observations were available, all with low phosphorus concentrations taken at low flows. As with nitrate, the decrease noted in phosphorus concentrations with increasing flows indicates a likely dilution of point source inputs with stormwater runoff.

Under the current project, monthly routine and quarterly storm monitoring is occurring at four stations. These four stations from most upstream to downstream are stations 18828 (South Nolan at 38th St in Killeen), 11913 (South Nolan at Roy Reynolds Rd in Killeen), 11910 (South Nolan at US 190 in Nolanville), and 11905 (South Nolan at Backstorm Crossing). While a detailed analysis of the monitoring data will be presented later in the project, a preliminary analysis of data collected between May 2013 and August 2014 shows some interesting trends in comparing routine with storm event data. Values in Figures 5-7 through 5-10 are compared for reference to criteria for bacteria (*E. coli* geometric mean = 126 cfs/100 mL) and screening levels for nutrients (nitrate = 1.95 mg/L, ortho-P = 0.37 mg/L, and total-P = 0.69 mg/L) from the TCEQ assessment guidance (TCEQ, 2012).

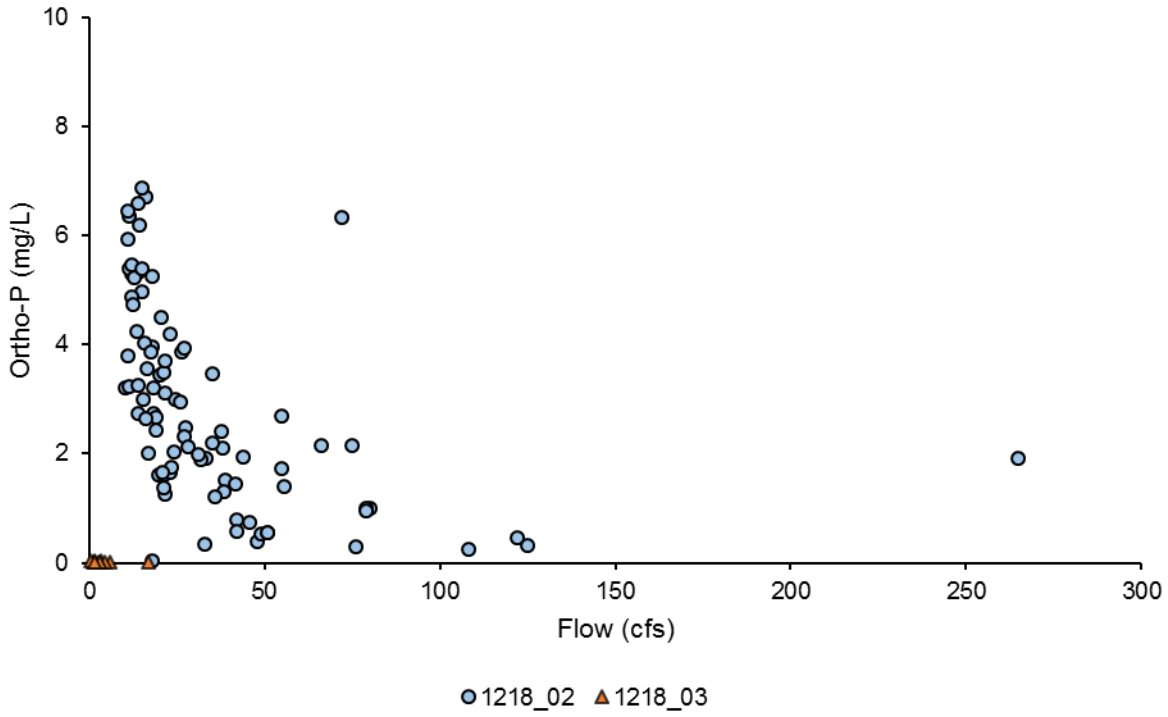

Figure 5-5 Flow versus ortho-P concentrations by AU.

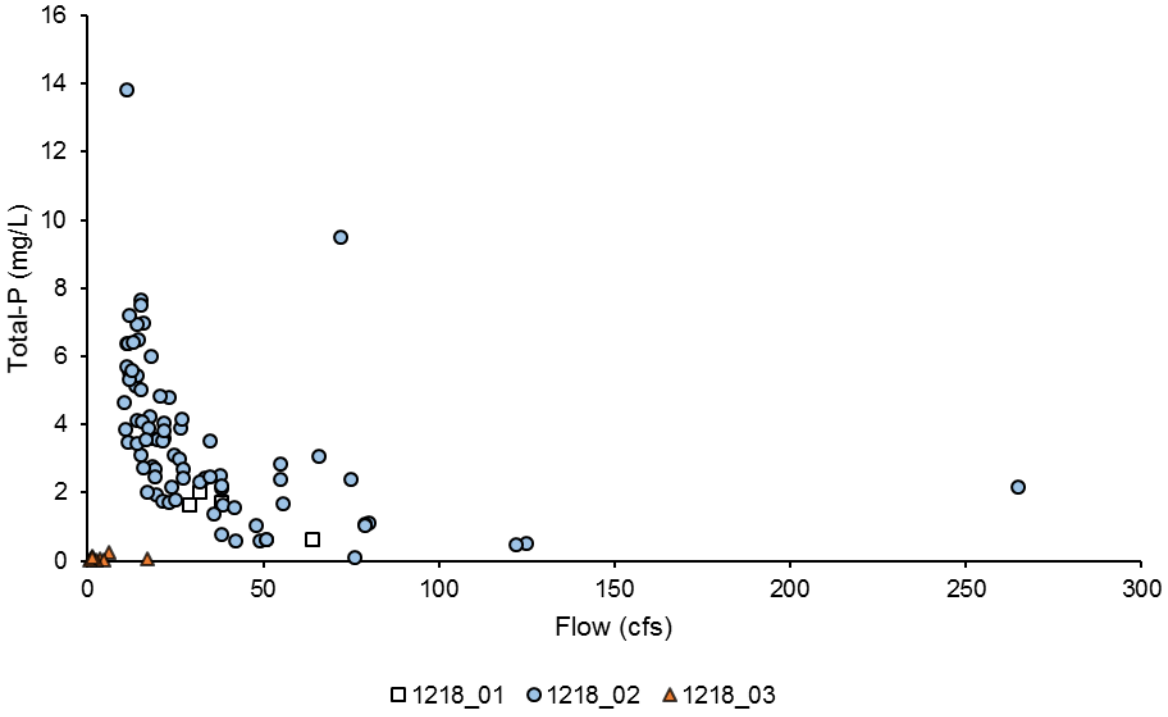

Figure 5-6 Flow versus total-P concentrations by AU.

While concentrations of bacteria were above the criterion for primary contact recreation during routine monitoring at all but station 18828, a very notable increase in geometric mean concentrations occurred with storm events compared to routine monitoring (Figure 5-7). Although historical data (Figures 5-1 through 5-3), did not indicate a significant relationship with flow, there does appear to be a large nonpoint source contribution with storm runoff. This nonpoint source contribution may be from bacteria washing off the land as well as the suspension of instream bacteria with elevated flows. In contrast, nutrients showed a notable decrease in concentration with storm flow compared to routine monitoring for nitrate (Figure 5-8), ortho-P (Figure 5-9), and total-P (Figure 5-10). This likely indicates a dilution of point sources at baseflow with increasing stormwater runoff. Except at station 18828 under storm conditions, mean concentrations of nutrients were above nutrient screening levels.

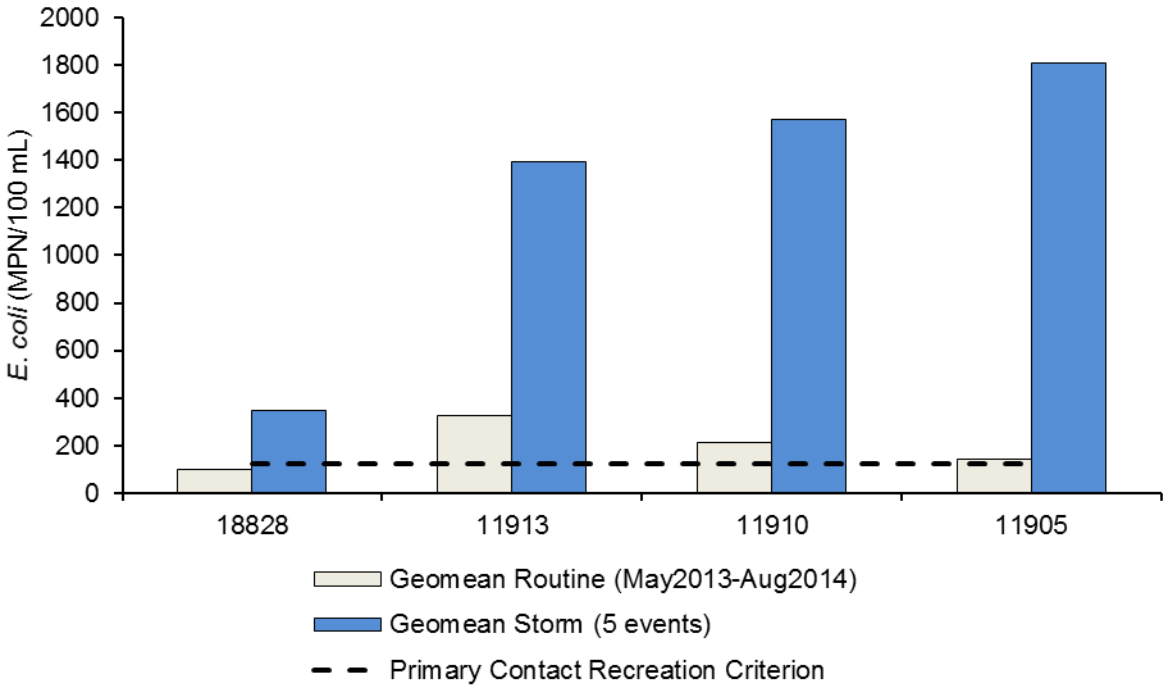

Figure 5-7 Preliminary analysis comparing geometric mean E. coli of routine with storm samples.

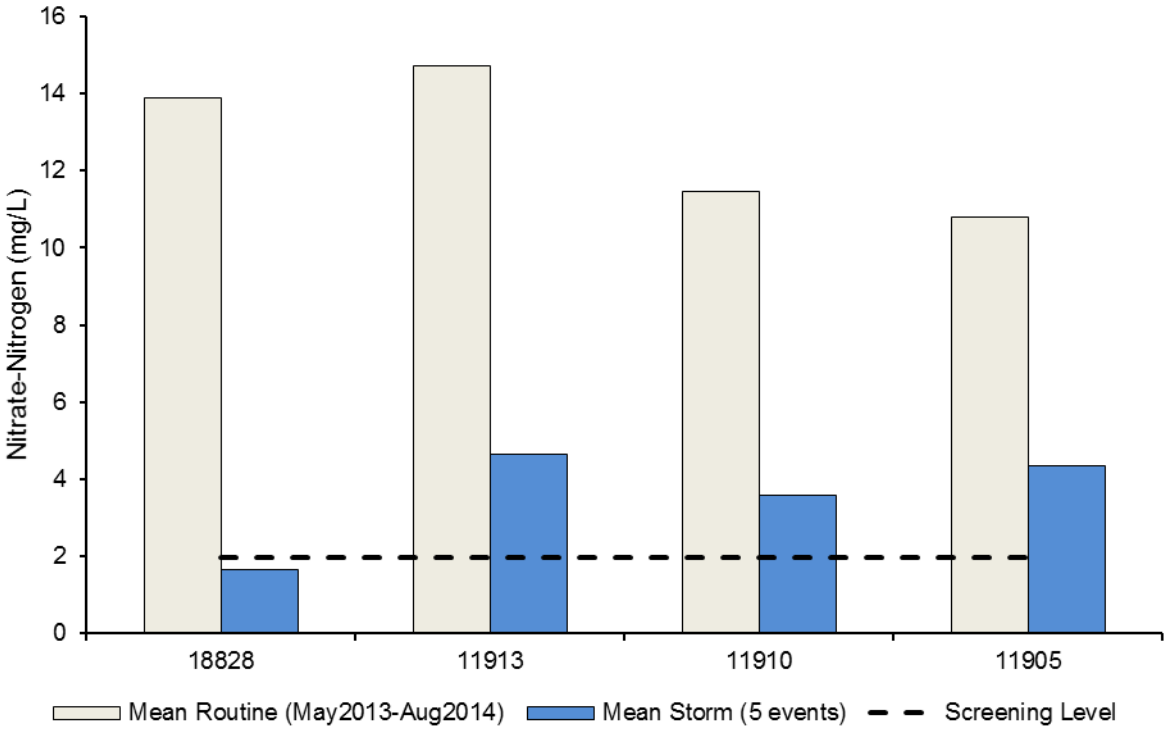

Figure 5-8 Preliminary analysis comparing mean nitrate of routine with storm samples.

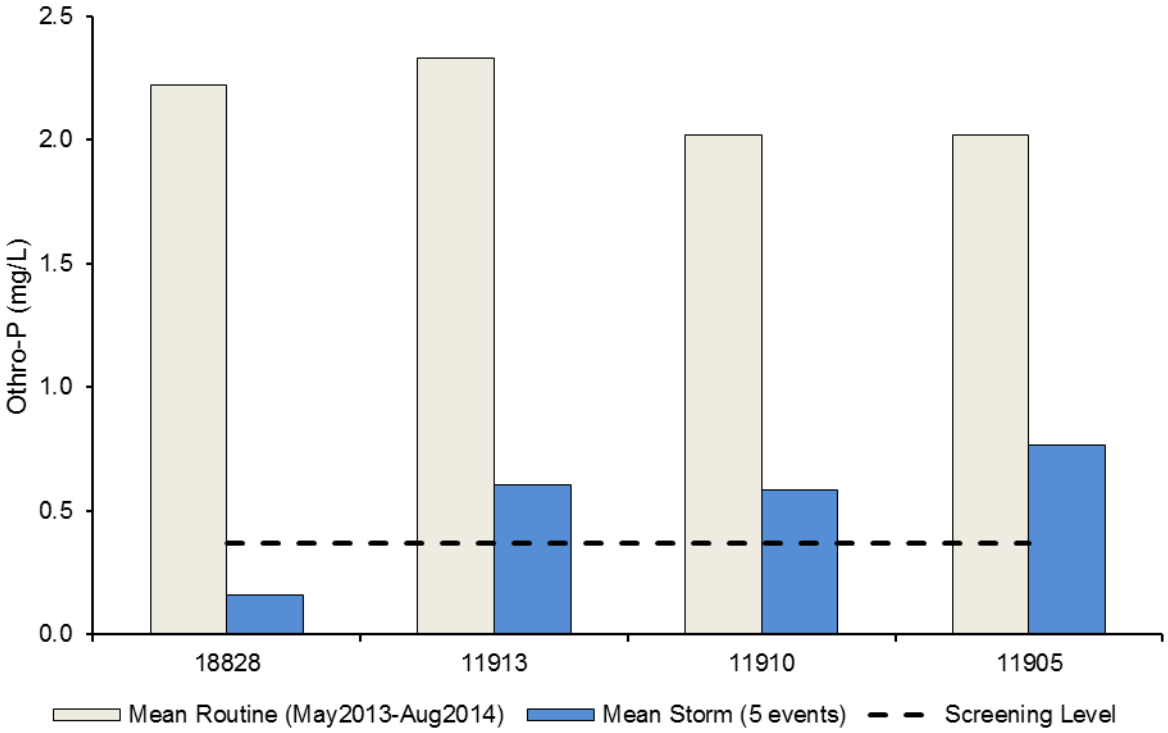

Figure 5-9 Preliminary analysis comparing mean ortho-P of routine with storm samples.

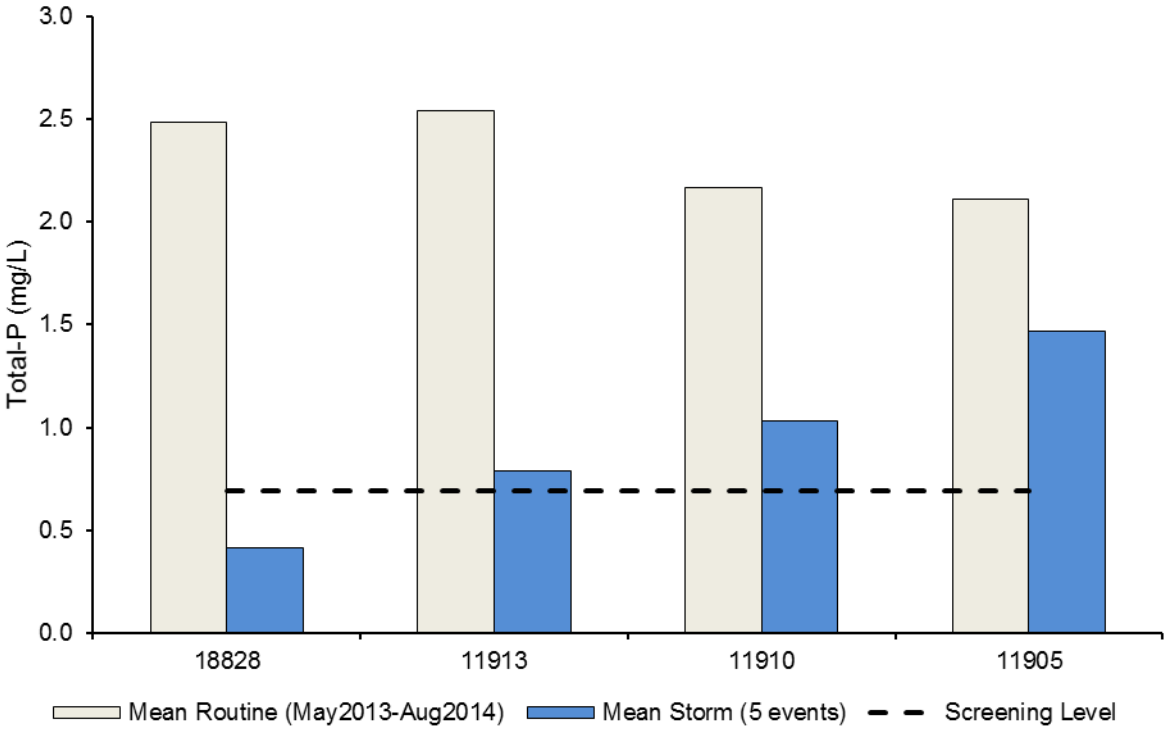

Figure 5-10 Preliminary analysis comparing mean total-P of routine with storm samples.

SECTION 6

The Next Step: Estimating Loadings by Source and Subbasin

While the current report focuses on identifying potential sources to develop meaningful management practices to facilitate water quality improvement, the relative loadings associated with various sources need to be estimated as well as needed reductions to reach improvement goals. Loadings and load reductions for bacteria will be assessed using the Spatially Explicit Load Enrichment Calculation Tool (SELECT) and Load Duration Curves (LDCs). For nutrients, as a concern within the watershed, only LDCs will be developed. An overview of how SELECT and LDCs will be applied is given below.

Source Identification

Sources and the potential bacteria contributions by each source will be identified by sub-watershed using the Spatially Explicit Load Enrichment Calculation Tool (SELECT). The Spatial Sciences Laboratory (SSL) and the Biological and Agricultural Engineering Department at Texas A&M University (TAMU) developed SELECT as a screening model to calculate potential contaminant-loads resulting from various sources in a watershed and spatially references these loadings via an AcrGIS environment (Teague et al., 2009). This report along with the data inventory report (see McFarland and Adams, 2015) provides information on the needed inputs for SELECT as SELECT requires a thorough characterization of land uses within the watershed well as information on the population density of people, livestock, pets, and wildlife (Table 6-1). While SELECT was developed for rural watersheds, the urban area as represented by point sources from WWTFs and MS4 areas can also be considered (e.g., Ling et al., 2012).

Load Estimation

To estimate loadings and load reductions needed, load duration curves (LDCs) will be developed for at least four locations within the watershed (Table 6-2). Load Duration Curves are a simple and an effective first-step methodology to obtain loadings under varying flow regimes (EPA, 2007; Cleland, 2003). A duration curve is a graph that illustrates the percentage of time during which a given parameter's value is equaled or exceeded. For example, a FDC uses the hydrograph of the observed or estimated stream flows to calculate and depict the percentage of time a given flow is equaled or exceeded. A LDC, which is related to the FDC, shows the corresponding relationship between the contaminant loadings and stream flow conditions at the monitoring site. In this manner, it assists in determining patterns in pollution loading (point sources, nonpoint sources, erosion, etc.) depending on the streamflow conditions.

These LDCs will be developed using historical data and additional project-collected data focusing on the four storm monitoring stations. The continuous stream level data collected at these four stations will be used to aid in estimating historical flows as outlined in the project modeling QAPP. Based on the observed patterns, needed loading reductions can be estimated for target or criterion levels associated with water quality restoration (EPA, 2007).

Table 6-1 Summary of data needs for running SELECT.

Type of Data	Units	Use	Data Source
Spatial GIS data, Land use and cover	30-m resolution, 16 categories	Land use and cover categories for associating with bacteria loadings from various sources	Multi-Resolution Landuse Consortium National Land Cover Database
Spatial GIS data, Soils	Soil mapping units	Used in conjunction with the location of rural households to estimate risk of septic system failures	Natural Resources Conservation Service (NRCS) Soil Survey Geographic (SSURGO) database
Location permitted discharge facilities, average monthly discharge	Location (latitude/longitude) & permitted average monthly discharge (MGD)	Used to define potential point sources of bacteria and nutrients	TCEQ Information Resources Division Central Registry or USEPA Enforcement & Compliance History Online (ECHO) website or directly from permitted facilities
Spatial GIS, Population data at various scales	Density down to blocks, as needed	Used to indicate population density in urban and rural areas	U.S. Census Bureau
Spatial GIS, Urbanized Areas	Spatial boundaries	Used to indicate municipal boundaries	U.S. Census Bureau
Spatial boundaries for counties and cities	Spatial boundaries	Used to indicate county boundaries and aid with city boundaries	Texas Natural Resources Information System (TNRIS) StratMap Boundaries with modifications, as provided, from municipalities
MS4 boundaries	Spatial boundaries	Used to indicate MS4 permit boundaries for urbanized areas	U.S. Census Bureau
Spatial GIS, point data	Household locations	Used to define rural population density with regard to septic systems and potential failure rates in conjunction with sewer service boundaries	U.S. Census Bureau

Type of Data	Units	Use	Data Source
Spatial GIS, Stream layer	Line data	To define location of stream segments	National Hydrography Dataset (NHD)
Spatial data, livestock density	County level estimates adjusted to watershed area for major livestock groups	Used to estimate livestock density throughout the watershed	USDA Census of Agriculture
Spatial wildlife density	Deer density and other pertinent species, as available	Used to estimate deer density throughout the watershed	Texas Parks & Wildlife Department surveys and/or information from biologists
Spatial, pet density	Dog density per household	Used to estimate dog density throughout the watershed	American Veterinary Medical Association (2012) and stakeholder input
Spatial, feral hog density	Feral hog density	Used to estimate feral density throughout the watershed	TPWD, literature values and stakeholder input
Rates of fecal production	cfu/day	Used to estimate potential bacteria loads for various sources (i.e., feral hogs, deer, dogs, cattle or other livestock, and WWTF discharges)	EPA and literature values
Wastewater treatment facility (WWTF) discharges	Discharge rates and bacteria concentration data	Used to estimate bacteria loadings associated with WWTF discharges	TCEQ Information Resources Division Central Registry, USEPA Enforcement & Compliance History Online (ECHO), or directly from permitted facilities
Spatial, boundaries for sewer service areas	Spatial boundaries	Used to define areas on sewer based on sewer Certificates of Convenience and Necessity (CCNs) and municipal boundaries	Public Utility Commission of Texas & Municipal boundaries (TNRIS)
Spatial GIS data, Digital Elevation Models (DEMs)	30 meter resolution	Delineation of watershed and subwatershed boundaries	National Elevation Dataset from USGS

Table 6-2 Summary of data needs for developing FDCs and LDCs.

Type of Data	Units	Use	Source
Time series, daily streamflow	Average daily (cfs)	Ranking of daily flow conditions for stream sites used for LDCs	United States Geological Survey (USGS) and direct project data
Concentration at various points in time	mg/L for nutrients and MPN/100mL or colonies/100mL for bacteria	Concentration of nitrates, orthophosphorus, total phosphorus and bacteria for LDCs.	TCEQ SWQMIS and direct project data
Instantaneous flow measurements collected with concentration data	cfs	Flow data to relate concentrations LDCs.	TCEQ SWQMIS and direct project data
Spatial data, location of existing SWQM stations	Latitude/ longitude	Define location of stations within the watershed with existing water quality monitoring data in SWQMIS	TCEQ SWQM Clean Rivers Program
Spatial GIS data, Digital Elevation Models (DEMs)	30 meter resolution	Delineation of watershed and subwatershed boundaries	National Elevation Dataset from USGS
Wastewater treatment facility (WWTF) discharges	Permitted discharge rates	Used to estimate bacteria loadings associated with WWTF discharges	TCEQ Information Resources Division Central Registry, USEPA Enforcement & Compliance History Online (ECHO), or directly from permitted facilities
MS4 Areas	Percent land area above LDC sites	Used to estimate bacteria loadings associated with MS4 areas	U.S. Census Bureau urbanized areas

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Appendix A

Agencies Contacts

Agency
Bell County
Bell County Master Gardeners
Bell County Public Health District
Bell County Water Control and Improvement District No. 1
Bell County Water Control and Improvement District No. 3
Bell County Water Control and Improvement District No. 6
Belton Area Chamber of Commerce
Belton Independent School District
Blackland Research and Extension Center
Brazos River Authority (BRA)
Central Texas Chapter of Texas Society of Professional Engineers
Central Texas College
Central Texas Council of Governments
Central Texas Homebuilders Association
Central Texas Master Naturalists
Central Texas Soil and Water Conservation District No. 509
Central Texas SWCD #509
City of Belton
City of Belton Public Works Director/City Engineer
City of Harker Heights
City of Killeen
City of Killeen - City Engineer
City of Killeen Planning & Zoning Commission
City of Killeen Recycling Center
City of Killeen Waste Management
City of Killeen/Keep Killeen Beautiful
City of Nolanville
Clearwater Underground Water District
Clearwater Underground Water District
Coryell County Precinct 1 Commissioner
Downtown Killeen Merchants' Association
Fort Hood
Fort Hood - Dept. of Public Works

Agency
Fort Hood Area Association of Realtors
Fort Hood Recycle Operations
Greater Killeen Chamber of Commerce
Harker Heights Chamber of Commerce
Killeen Independent School District
Lake Stillhouse Clean Water Steering Committee
Lone Star Chapter Sierra Club
Natural Resources Conservation Service (NRCS)
Texas Commission on Environmental Quality - Waco, Regional Office
Texas A&M Central Texas
Texas A&M Forest Service
Texas AgriLife Research
Texas Commission on Environmental Quality (TCEQ)
Texas Department of Transportation (TexDOT)
Texas Parks and Wildlife Department (TPWD)
Texas Rivers Conservation Association (TRCA)
Texas State Soil and Water Conservation Board (TSSWCB)
United States Environmental Protection Agency (USEPA)
United States Geological Survey (USGS)